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Deciphering the impact of diagenesis overprint on negative $\delta^{13}C$ excursions using rock magnetism: Case study of Ediacaran carbonates, Yangjiaping section, South China

Mélina Macouin [a,b,c,*], Magali Ader [d], Marie-Gabrielle Moreau [e], Charles Poitou [e], Zhenyu Yang [f], Zhimming Sun [f]

[a] Université de Toulouse, GET, 14 avenue E. Belin, F-31400 Toulouse, France
[b] GET/OMP, UMR CNRS 5563, Université Paul-Sabatier, 14 avenue E. Belin, F-31400 Toulouse, France
[c] IRD, UR 154, GET, 14 avenue E. Belin, F-31400 Toulouse, France
[d] Équipe de géochimie des isotopes stables, Institut de Physique du Globe de Paris, Sorbonne Paris Cité, Univ. Paris Diderot, UMR 7154 CNRS, F-75005 Paris, France
[e] Équipe de Paléomagnétisme, Institut de Physique du Globe de Paris, Sorbonne Paris Cité, Univ. Paris Diderot, UMR 7154 CNRS, F-75005 Paris, France
[f] Institute of Geomechanics, CAGS, Beijing, China

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A B S T R A C T

Rock magnetism is used here to investigate the genesis of one of the puzzling negative carbon isotopic excursions of the Neoproterozoic in the Yangtze platform (South China). A detailed characterization of the magnetic mineralogy, which includes low-temperature and high-field magnetometry and classical magnetic measurement (ARM, IRM, susceptibility), was therefore performed along upper Doushantuo and lower Dengying Formations outcropping in the Yangjiaping section. The derived magnetic parameters show variations that can be interpreted as variations in magnetic grains size and in oxide contents. They show that the magnetic content is significantly reduced in samples presenting negative $\delta^{13}C_{calcite}$ values. We interpret this as a result of magnetite dissolution and secondary carbonate precipitation during early diagenesis bacterial sulfate reduction.

Combined with C and O isotopic data, paleomagnetic techniques thus show that the upper Doushantuo–lower Dengying negative excursion of the Yangjiaping section is largely due to diagenesis, although the preservation of a genuine $\delta^{13}C$ excursion of lower magnitude from +7‰ down to 0‰, instead of down to −9‰ as usually considered, cannot be ruled out. A corrected $\delta^{13}C_{carbonate}$ chemostratigraphic curve is therefore proposed. The unambiguous identification of a strong diagenetic component for this excursion casts doubts on the primary nature of other potentially time equivalent negative excursions of the Yangtze platform and thus to its correlation to negative excursions in other cratons (i.e. Shuram excursion). More generally, this study illustrates the potential of magnetic mineralogy characterization, a low cost, time efficient and non-destructive technique, as screening tool for diagenetic overprints of $\delta^{13}C$ and $\delta^{18}O$.

1. Introduction

Some puzzling negative Carbon isotopic excursions (reaching at least −5‰ and as much as −12‰), that dwarf any Phanerozoic variations, occurred several times at the end of the Precambrian (Halverson et al., 2010, 2005; Hoffman and Schrag, 2002; Knoll, 2000). By analogy with the Phanerozoic, it has long been suggested that these negative excursions can be used as a global correlation tool. This assumption was justified by the fact that most of the negative excursions are correlated to severe Neoproterozoic glaciations that punctuate this unique interval in Earth's history (e.g. Halverson et al., 2010, 2005; Knoll, 2000). This is of great importance for these periods since direct radiometric dating is generally hampered by the lack of suitable rocks and the fossil record is parse, rendering biostratigraphy of limited use (Knoll and Walter, 1992). Moreover, if true, this assumption also implies that $\delta^{13}C$ variations are a proxy for global carbon cycle perturbations, which would have been especially strong and frequent at this period. The causes for these putative carbon cycle perturbations are still under debate. Methane release (Bjerrum and Canfield, 2011; Jiang et al., 2003; Kennedy et al., 2001), snowball Earth (Hoffman and Schrag, 2002), overturn of a redox-stratified ocean (Grotzinger and Knoll, 1995; see also Shields, 2005) or advent

* Corresponding author at: GET/OMP, UMR CNRS 5563, Université Paul-Sabatier, 14, avenue Edouard Belin, 31400 Toulouse, France. Tel.: +33 5 61 33 26 56; fax: +33 5 61 33 25 60.
E-mail address: melina.macouin@get.obs-mip.fr (M. Macouin).

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of new species (Condon et al., 2005) have been advocated. However, major indeterminations remain concerning both the synchronism and the global extension of these negative excursions. Hence, the onshore–offshore negative $\delta^{13}C$ gradients in some Neoproterozoic basins have been interpreted as resulting from a redox stratification of the ocean (e.g. Ader et al., 2009; Giddings and Wallace, 2009a, 2009b; Jiang et al., 2007, 2011; Li et al., 1999; Shen et al., 2011). ^{13}C-depleted carbonate would have essentially precipitated from deep anoxic water, which DIC was ^{12}C-enriched by organic matter mineralization. Spatially restricted and not necessarily synchronous negative excursions would then indicate a transitional time interval during which the dissolved organic matter in the anoxic deep ocean inherited from the early Proterozoic would be progressively oxidized by an increasing sulfate flux to the oceans (Shen et al., 2011).

All these hypotheses, however, require that these excursions record a primary environmental signal rather than a diagenetic overprint. Recently, diagenetic overprinting has been reconsidered to explain the $\delta^{13}C/\delta^{18}O$ arrays often associated with Neoproterozoic negative $\delta^{13}C$ excursions (Derry, 2010a, 2010b; Knauth and Kennedy, 2009; Swart and Kennedy, 2011). $\delta^{13}C_{carbonate}$ is indeed liable to decrease during diagenetic processes if secondary carbonates precipitate from ^{12}C-enriched pore fluids (see among others Ader and Javoy (1998), Coleman and Raiswell (1981), Irwin et al. (1977), Pierre and Rouchy (2004) and Rosales et al. (2001)). Knauth and Kennedy (2009) argue in favor of a diagenetic overprint of the carbonate $\delta^{13}C$ (and $\delta^{18}O$) signal due to large groundwater influx of dissolved carbon derived from terrestrial phytomass (i.e. meteoric diagenesis). Derry (2010b) argues in favor of fluid–rock interactions with high pCO_2 fluids during burial diagenesis for the largest-known carbon isotope excursion (i.e. the Shuram Excursion). But if, as envisaged by Grotzinger et al. (2011) in their review, the Shuram Excursion was a global diagenetic event, it must have been specific of this time period and remains to be identified. Indeed, none of the presently known diagenetic mechanisms seems liable to account for a globally distributed diagenetic isotope overprint event.

Given the implications of the interpretation of negative excursions in terms of changes in the global carbon cycle, ocean chemistry, or even diagenetic mechanisms during the Neoproterozoic, the issue of diagenesis is of paramount importance. Existing diagenetic tracers being too ambiguous to clearly identify all types of diagenetic overprints (Derry, 2010a, 2010b), new diagenetic proxies and different approaches are needed to evaluate the quality of the $\delta^{13}C_{carbonate}$ record.

We focus here on iron-bearing minerals with characteristic magnetic properties. They are ubiquitous in a sedimentary environment. Their mineralogy, concentration and grain size distribution are essentially controlled by the detrital input (i.e. by climatic factors) and by depositional and diagenetic redox conditions and can be investigated by standard magnetic methods (see for

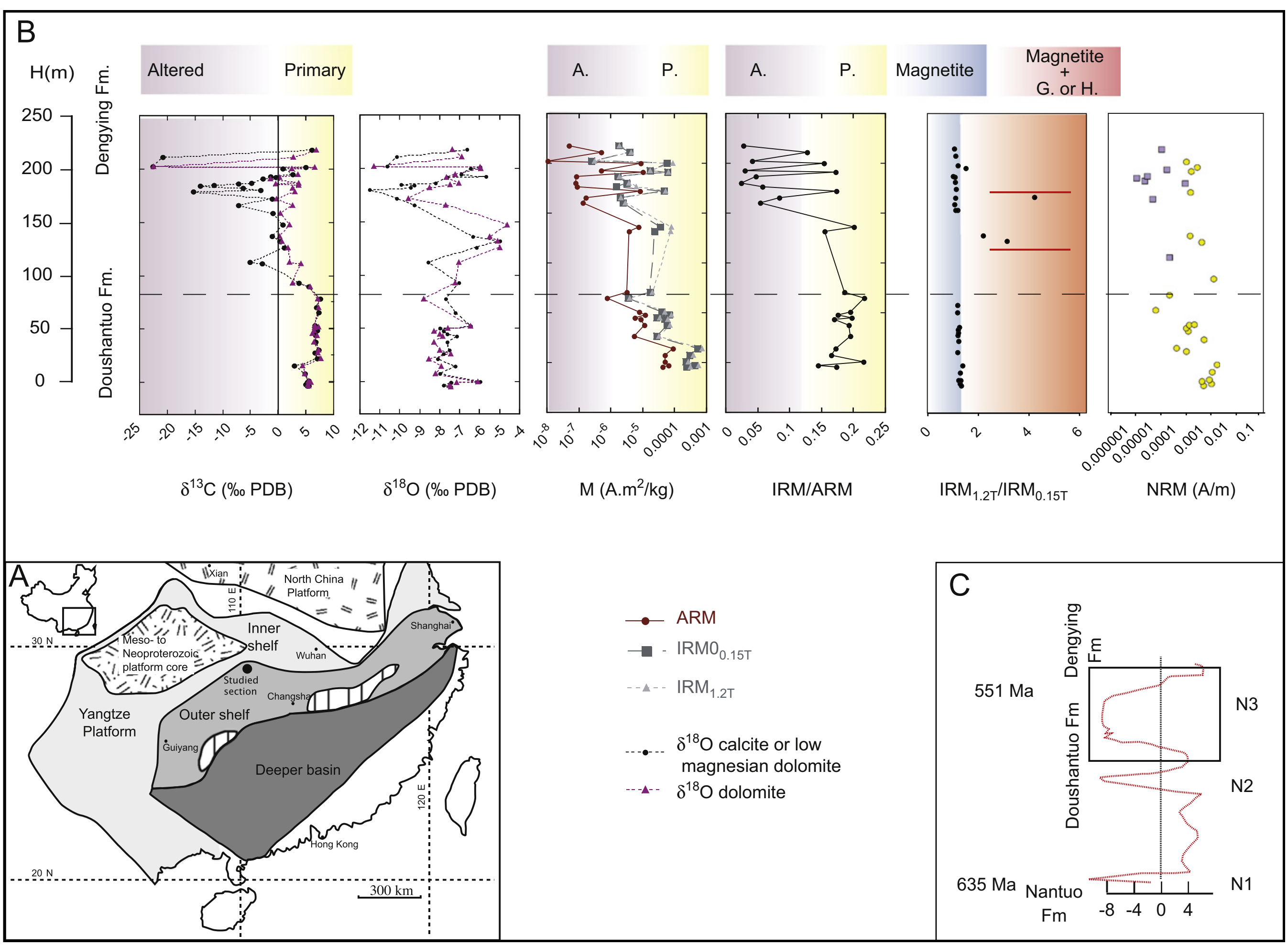

Fig. 1. (A) Paleoenvironmental map of the Yangtze Platform, China, during late Neoproterozoic time (modified from Steiner et al. (2001) and Dobrzinski and Bahlburg (2007)) and location of the studied section. (B) C and O isotope profils and evolution of $IRM_{0.15\ T}$, $IRM_{1.2\ T}$, ARM, ARM/IRM and the Natural Remanent Magnetization (NRM) in the Upper Doushantuo beds. For the NRM, dots are samples that provide the Characteristic Remanent Magnetization (ChRM) and squares are either remagnetized or unstable samples (from Macouin et al. (2004)). (C) Synthetic C-isotope chemiostratigraphy of the late Neoproterozoic generally used for South China. Modified from Jiang et al. (2011).